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On the Non-Visual Perception of the Length of Lifted Rods

1921

BY

LOUIS BENJAMIN HOISINGTON

A THESIS

Presented to the Faculty of the Graduate School of Cornell University in Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

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ON THE NON-VISUAL PERCEPTION OF THE LENGTH OF LIFTED RODS[1]

By Louis B. Hoisington

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I. Problem

This study has been undertaken as a preliminary to the study of what is known as 'eccentric projection.' We have sought to discover and to analyze the perception of length which arises when light rods, held horizontally, are lifted a moderate distance in the vertical dimension. We have also been successful in synthetizing this perception of length from the data of analysis. We believe that the ground is thus prepared, logically and psychologically, for an attack upon the more complex perception which appears when a rod, held in the hand, is brought into contact with wall or floor.[2]

II. Observers

The observers were Mr. P. Cavanaugh (Ca), Miss C. Comstock (Co), Dr. C. L. Friedline (F), Dr. J. M. Gleason (G), the writer (H), Mr.

[1] From the Psychological Laboratory of Cornell University.

[2] Since the references to this type of experience are concerned almost exclusively with 'eccentric projection,' we omit an historical review. See, however, H. Lotze, *Microcosmus* (tr. E. Hamilton and E. E. C. Jones), I, 1885, 586 ff.; esp. on the perception of added height due to head and foot coverings, 592 f.

H. S. Liddell (L), Mr. E. S. Neal (N), Miss A. K. Sullivan (S), and Dr. M. J. Zigler (Z).[3] All were graduate students or instructors in the department of psychology. They varied considerably in training: Ca and N were unpractised; Co, L, S and Z were but moderately experienced; F, G and H were trained observers.

H and Z served throughout; F, G and N during the first half of the work; L and S during the second half; Ca and Co during the last quarter only. The observers, except H, worked without knowledge of problem or conditions. The plan of the investigation called for observation under a long series of but slightly varying conditions, and thus made heavy demands upon the patience and skill of the observers. The demands, as the results show, were adequately met.

III. Procedure and Apparatus

The method of procedure was twofold: quantitative, by the method of Constant Stimulus Differences, and qualitative, by way of introspective report. In the method of constant stimulus differences, following Urban, we used five comparative stimuli: objective equality, and two steps above and below; except in one check-series, where all rods were objectively equal.

The experimental work divides itself into four principal sections—A, B, C and F—in accordance with the nature of the rods used or the end sought. In section A (10 series) we used rods, planed from seasoned poplar wood, one-half inch in diameter, which averaged 1 gr. in weight per 2.85 cm. of length. The handles, turned from white pine,, were quite heavy relatively to the weight of the rods. In section B (7 series) the rods, planed from seasoned oak, were three-quarters of an inch in diameter, and averaged 1 gr. in weight to every 0.52 cm. of length. The handles, also turned from white pine, were both absolutely and relatively much lighter than those used in section A. In section C (1 series) we aroused the experience of length without recourse to rods, synthetically. In section F (6 series) we sought to determine more exactly the effective factors in the perception of the length of lifted rods. To this end we used the lighter rods with a new set of lighter handles. We added weights to the rods, to make them conform to certain mathematical requirements; hence they were about double the weight of the rods of section A. We give the data for the physical properties of the rods in Table I.[4]

This table shows three characteristic ways in which rods may differ: length, weight and center of mass. All three moments may differ for every rod in a set; or any one moment may be kept constant for every rod, the other two varying; or two may be constant for every rod in the set, the other varying. We thus obtain seven different combinations. Use of the same combinations with the light and the heavy rods gave fourteen series; the first seven of section A and all

[3] Thanks are due to Miss M. Kincaid and to Dr. C. W. Bock, who acted as experimenters for H.

[4] The handles for section A were 15.4 cm. long and weighed 70 gr.; for sections B and D, they were 15 cm. long and weighed 30 gr.; for sections E and F they were 10 cm. long and weighed 30 gr. The centers of mass in series A III lay 35, 33.5, 31, 29.5, and 27 mm. back from the front end of the handle.

of section B.[5] In addition, we ran a control-series (A VIII), in which all the rods were equal; a practice-series (A IX), which was

TABLE I.

Series	Total Length of Rod and Handle	Center of Mass from Handle	Weight of Rod and Handle
A I	74, 79.7, 85.4, 91.1, 96.8 cm.	11, 23, 35, 47, 59 mm.	96, 98, 100, 102, 104 gr.
A II	Same as A I.	Same as A I.	All 104 gr.
A III	All 22.9 cm.	See foot note	Same as A I.
A IV	Same as A I.	All 59 mm.	Same as A I.
A V	Same as A I.	All 59 mm.	All 104 gr.
A VI	All 85.5 cm.	Same as A I.	All 100 gr.
A VII	All 85.5 cm.	All 35 mm.	Same as A I.
A IX	Same as A I.	Same as A I.	Same as A I.
A X	Same as A I.	Same as A I.	Same as A I.
B I	85, 87, 89, 91, 93 cm.	222, 233, 244. 255, 266 mm.	192, 196, 200, 204, 208 gr.
B II	Same as B I.	Same as B I	All 208 gr.
B IIIa	All 25.5 cm.	21, 23, 25, 27, 29 mm.	Same as B I.
B IIIb	All 89 cm.	Same as B I.	Same as B I.
B IV	Same as B I.	All 244 mm.	Same as B I.
B V	Same as B I.	All 244 mm.	All 208 gr.
B VI	All 89 cm.	Same as B I.	All 200 gr.
B VII	All 89 cm.	All 244 mm.	Same as B I.
C I	Synthetic Series.		
D I	Same as B I in all respects. Wt. judgments.		
E I	All 82.5 cm.	All 250 mm.	60, 80, 100, 120, 140 gr.
F I	All 82.5 cm.	74, 76.9, 80, 83.2, 86.7 mm.	208, 204, 200, 196, 192 gr.
F II	All 82.5 cm.	206, 222, 240, 261, 284 mm.	111.6, 105.85, 100, 94, 87.9
F III	All 82.5 cm.	Same as F II.	116, 108, 100, 92.2, 87.9 gr.
F IV	All 82.5 cm.	202, 220, 240, 262, 285 mm.	All 100 gr.
F V	All 82.5 cm.	Same as F IV.	113.5, 106.6, 100, 94, 87.6
F VI	All 82.5 cm.	Same as F IV.	119, 109, 100, 91.7, 84.2 gr.

[5]The 7 series of section B duplicate the corresponding series of section A in the ordering of the three physical moments.

a repetition of A I, at the end of the year's work; a passive series (A X), in which the support of the rod, after *O* had grasped the handle loosely, fell away gently; the synthetic series (C I); a weight-series, in which the *O*'s judged the comparative weights of the rods; two short series in which a wooden 'spoon,' securely bound to the arm, served as artificial thumb or forefinger to take up the 'kick' or the 'pressure' as the case demanded; and a series (E I) in which center of mass and length were the same for every rod, but weight varied very considerably. Lastly, we ran a somewhat irregular lot of series (Section F) in the hope, as before stated, of finding some further cue to the analysis of the perception. We worked out the weight and the center of mass that would give us a desired ratio of 'kick' to 'pressure,' and increased this ratio by relatively equal amounts for every one of the five variable rods (F I and II). In this way we hoped to find an optimal setting of the rods—i. e., that combination of physical moments which should give the smallest D. L., or whatever corresponds with that determination. We also (F III, V and VI) placed weights on the rods at such points that the 'kick' or the 'pressure' remained constant for every rod in the set.[6] In F III the steps were relatively equal increments of the variable pressure. Finally (F IV, V and VI) we took for our steps relatively equal increments of center of mass. In sections A, B, D and E the steps were absolutely equal units of weight, of length or of center of mass. There were, then, one, two or three sets of equal but disparate increments, acocrding to the number of variable factors for the given set of rods.

In an experimental group 20 pairs of rods were presented in a haphazard order, in which every one of the variables occurred an equal number of times. On the completion of a group, *O* rested for a few minutes. The number of groups completed in an hour of observation varied from three to five. Fifty judgments in all were made with every variable in every series, except the first in A and B, when for the sake of practice the number was increased to 100.

The time elapsing between presentations of the rods was, at first, regulated by a soundless metronome. The use of the metronome was discontinued after *E* had become practised. Six seconds intervened between the giving of the judgment and the presentation of the first rod of the next pair. We found that, with this interval, the tendency for the impression of the last rod of a preceding pair to carry over to the first of the succeeding pair was almost negligible. The second rod was taken up by *O* as soon as he was able after putting the first rod down. The time elapsing between the lifting of the second rod and the giving of the judgment varied considerably. The *O*'s were, of course, urged to give immediate judgments; if they reported an attitude of doubt or uncertainty, the pair was presented again at a later time. The time for lifting the rods and making the judgment, when the report was immediately rendered, averaged about 10 sec. Some *O*'s, however, were slow and deliberate in the act of lifting, while others made the lift very quickly.

We employed the two time-orders with equal frequency but in no regular sequence, so that any effects of warming-up or of practice

[6]Throughout this study we use the term 'kick' to designate the pressure-sensation at the base of the thumb stimulated by the up-thrust of the back end of the handle, and the term 'pressure' to designate the sensation in the forefinger stimulated by the down-pull of the outer end of the rod.

were equally distributed. *O* was not informed as to the time-order in any series. We found that, so long as he did not take a positive set or attitude toward time-order, there was complete uniformity in results. Some *O*'s showed a tendency to judge the second rod as 'longer' or as 'shorter' with a resulting difference in distribution for the two time-orders.[7] The results given are the averages for the two time-orders.

Since it was advisable that *O* should take all rods from the same place, we made a long narrow frame which slid back and forth with but little noise over round metal bearings and between greased guides, and placed it on a low table. We cut shallow notches with sloping sides 6 in. apart in the sidepieces of the frame, and faced the top of the notches with thin felt. The rods, placed in the notches, lay across the frame in the horizontal position with the handles projecting over the edge of the table toward *O*. Thus *O* took all rods from the same position, relatively to himself, since a small movement of the frame, made by *E*, brought the desired rod directly in front of him. We were able by means of this device to avoid a space-error.

The *O*'s sat blindfold during the observations. A counterbalanced screen left only the handles of the rods exposed. This screen remained down, so that the rods were completely covered, whenever the blind was removed. *E* marked the position of the chair for every *O*, so that he should sit, always with the chair in the same position, at full arm's length from the handles. *O* deposited every rod, as lifted, in a cloth-lined tray placed just above and to the right of the rod when in position to be taken up. This tray was shorter than the rods, except for series A III and B IIIa; hence *O* could get no cue to length when he put the rod down.

For the regular quantitative series the written instructions handed to the observers were: "You will be given two rods in succession. You are to raise them in the horizontal position, using a whole-arm movement and a loose grip upon the handle. You are to judge the length of the second rod in terms of the first; that is, you are to judge the second rod as longer than, equal to, or shorter than the first." For the introspective reports we took separate short series at the end of the regular groups. The additional instructions ran as follows: "You will make a full psychological report of the processes set up in the two experiences."

E's task was threefold: he shifted the sliding frame back and forth; he returned the rods from the tray to the frame; and he recorded the judgments and reports of *O*.

IV. Results

Our criterion for the adequacy of the perception of length is the ability to make comparative judgments. If the percep-

[7] On two different days, owing to a previous discussion with *E*, H assumed, without intending to do so, a time-order set. The results were comparable with those on other days if the set corresponded with the time-order given; if not, the results showed the discrepancy. In both cases *O* took the normal discriminative length-attitude at the next sitting. Following accepted practice, it would seem allowable, if *O* tends to note the time-order used, to tell him what the order is. But it appears best to say nothing about it, and to hold *O* to the attitude set up by the instructions.

tion changes in degree with variation of one or more of the physical moments of the stimuli, we shall expect a high percentage of 'shorter' judgments at the one extreme and a small percentage at the other, provided that the extremes have been well chosen. The opposite will be true of the 'longer' judgments. If, on the other hand, certain of the physical moments are not adequate stimuli to the perception, or affect it only indirectly through association and reflection, then, with these moments the sole variables, we shall expect a more irregular distribution of the comparative judgments; one with low extremes for either kind of judgment and with inversions, one with a probable excess of the 'equal' judgment. This is what we found. A certain factor (center of mass), when varied, gave typical cross-curves with low intersections; the other factors (length and weight) as variables gave flat curves with inversions and delayed responses.

The distributions of the comparative judgments for all *O*'s with the different arrangements of the physical moments (see Table I) are given in Figs. 1 to 26, where the abscissae represent the five variables, and the ordinates show the percentage that the number of judgments in each category (longer and shorter) formed of the total number of judgments given.

Length

It is clear that length, in and of itself, cannot affect the rod as a stimulus-object. It is impossible that length alone, apart from its usual connection with center of mass and weight, can affect a rod which functions as a lever. Center of mass and weight are the factors that enter into the computation of the moments of force. The pendular period of a rod is likewise dependent upon its center of mass. It is only in so far as air resists the motion of a rod that greater or lesser length, presenting a more or less extended surface, can be effective in experience. And it is out of the question that such a difference should be effective in the present experiment. In a trial synthetizing apparatus we used, without effect, a rod considerably longer than any of those of the regular series.

We, nevertheless, let length take its turn, along with the other two moments, at varying and remaining constant. The results (Figs. 5 and 15) show that, when length is the only variable, accurate judgments of difference in the length of the rods are impossible. The curves for all *O*'s are flat and irregular. These results should be compared with those obtained when all the rods in the set were equal (Fig. 8).

It must be remembered that, since weight and a center of mass out beyond the hand were present, the perception of length as such was possible and took place. The introspective reports can give us nothing new on this point.

Weight

Since we have ruled out length as a contributing factor to the length-perception, we are free to examine the series in which weight and length were both variables as well as the series in which weight alone varied (see Figs. 4, 7, 14 and 17). Scrutiny of these series shows that the influence of differences of weight upon judgments of comparative length is a complicated matter.

The adjustment of the physical moments in series A IV (Fig. 4) gave a rather large per cent. of 'shorter' judgments for the lightest rod; the per cents. for Z and N are 66 and 65 respectively. All *O*'s except F gave fewer judgments of 'longer' for this series when comparing the heaviest rod with the normal; F gave the same number for 'shorter' and 'longer' at the extremes.[8] The general flatness of the curves together with the inversions shows that here was no sufficient basis for judgments of comparative length. The preponderance of the judgment 'shorter' seemed to have, in large part, a temporal basis. Two time-factors were noted by the *O*'s; the one had to do with the quickness or slowness with which the pressure came on initially, the other, with the 'liveliness' or 'deadness' of the pressure. It was the former, according to the introspections, which came in most frequently in this series. The usual muscular innervation was greater than that required for lifting the light rod. As a consequence the rod came up with surprising suddenness. In almost every such case *O* judged the rod as shorter than the standard. The lightness of the rod came, readily enough, to carry an assigned meaning of length, in the same way that the 'secondary criteria' carry meanings in the domain of visual space-perception. It is to be doubted, however, whether the length-meaning was fully realized. It is much more probable that weight was the first item of perception immediately translated into length-terms; it set off the length-meaning without the full perception of length.

We turn now to the results of series A VII (Fig. 7), where there obtains a greater practice effect (for the effect of prac-

[8] Owing to a previous injury to the hand and wrist, F lifted the rods in a different manner from the other *O*'s. Her experience differed accordingly. Wrist-torsion made up a large part of the experience.

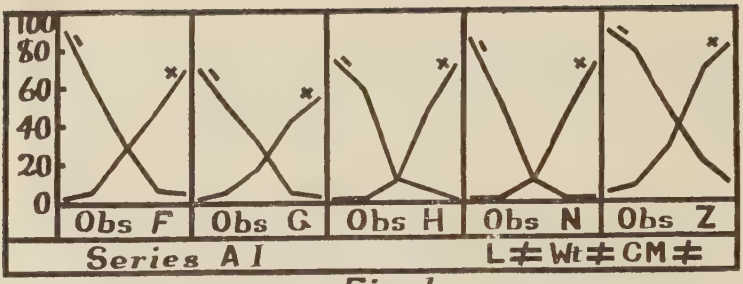


Fig 1

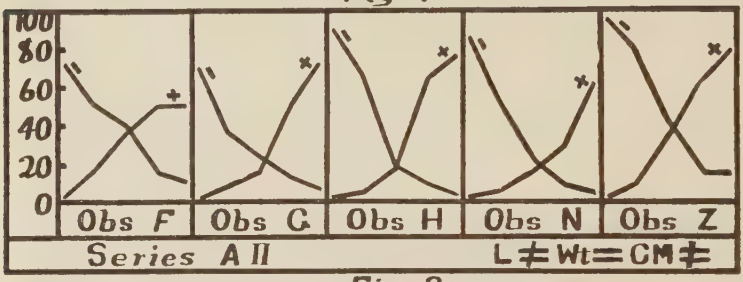


Fig 2

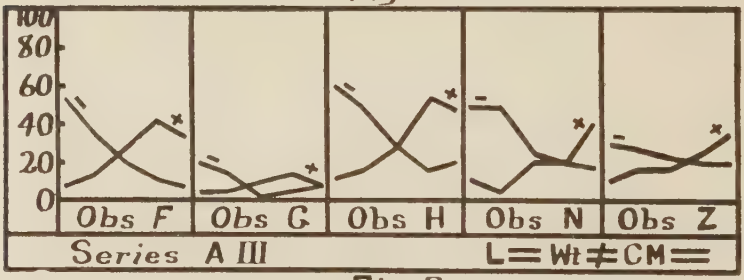


Fig 3

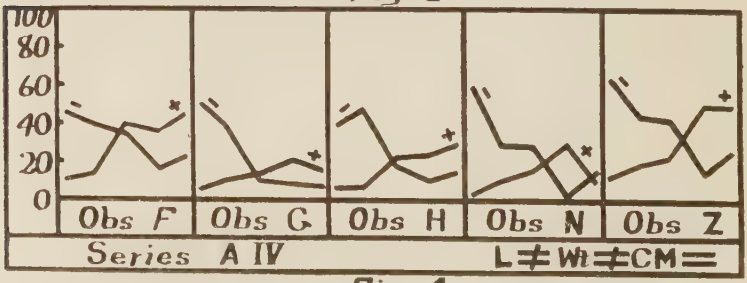


Fig 4

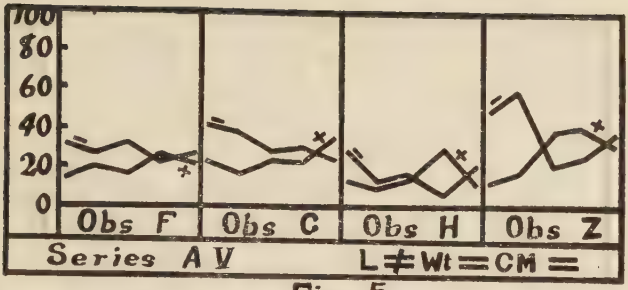


Fig 5

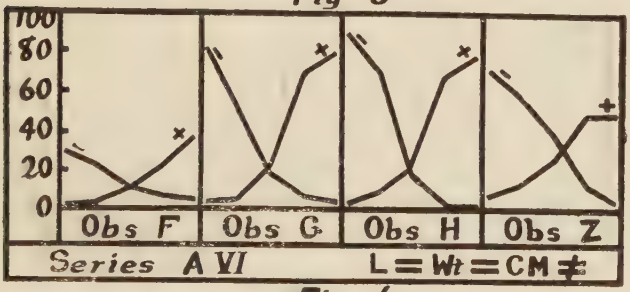


Fig 6

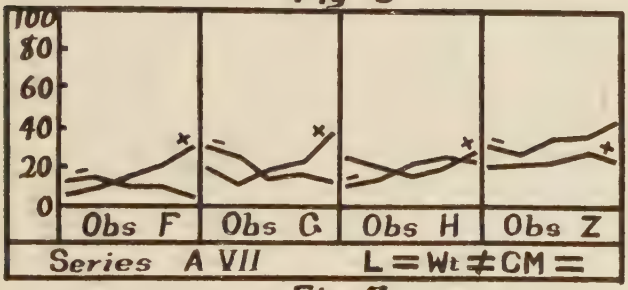
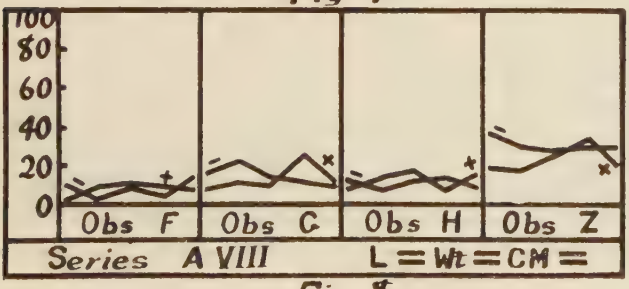


Fig 7



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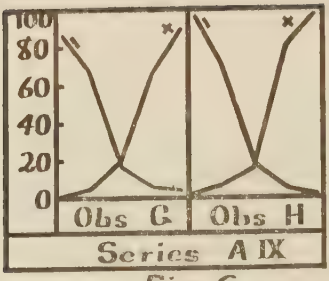

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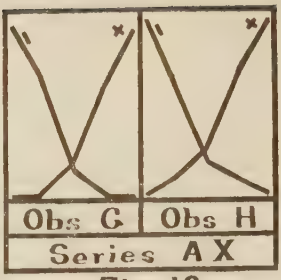

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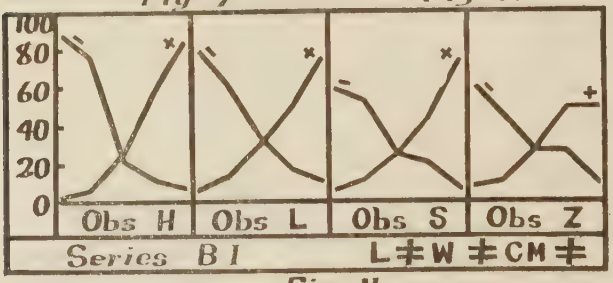

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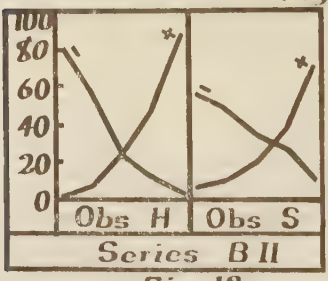

Fig 12

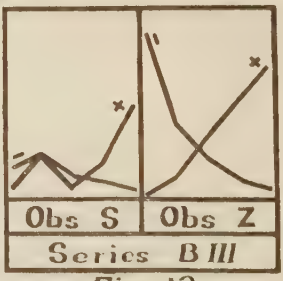

Fig 13

Fig 14

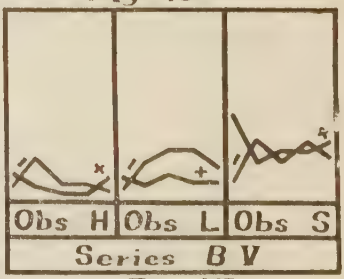

Fig 15

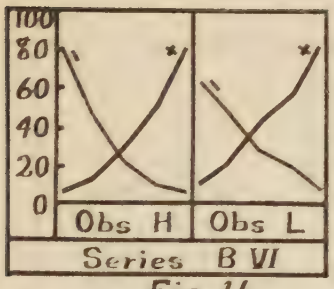

Fig 16

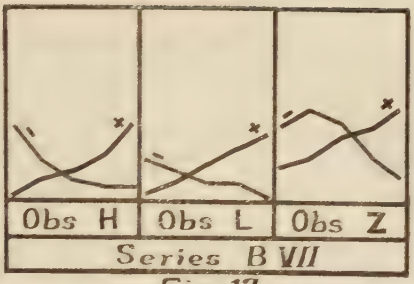

Fig 17

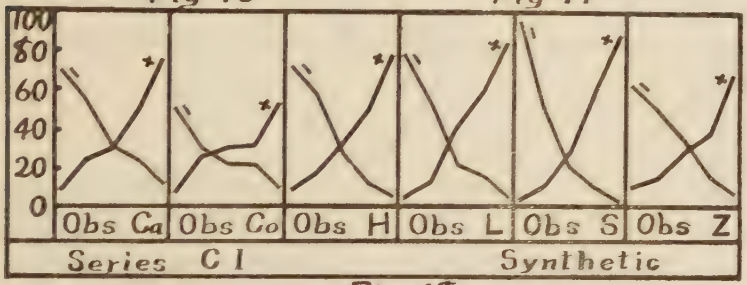

Fig 18

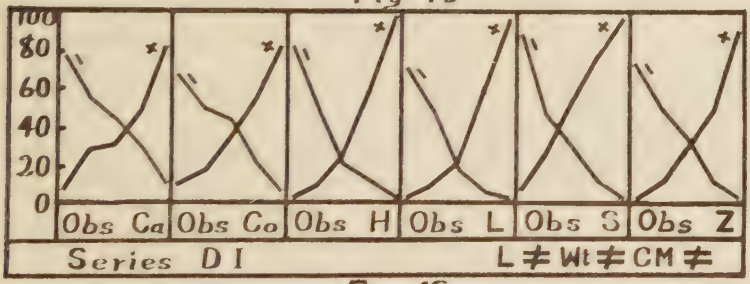

Fig 19

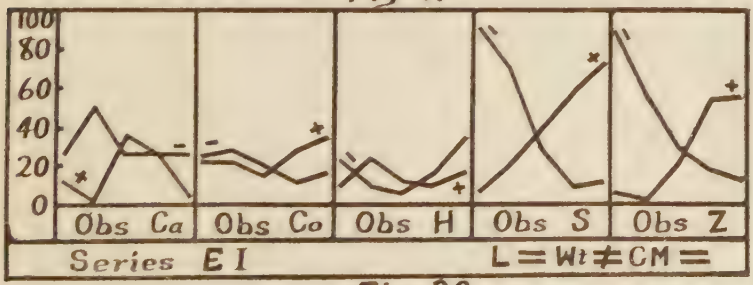

Fig 20

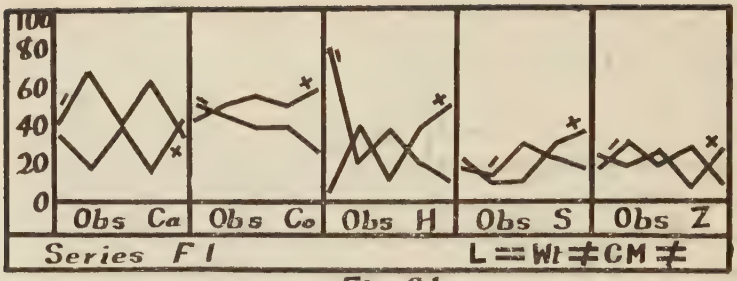

Fig 21

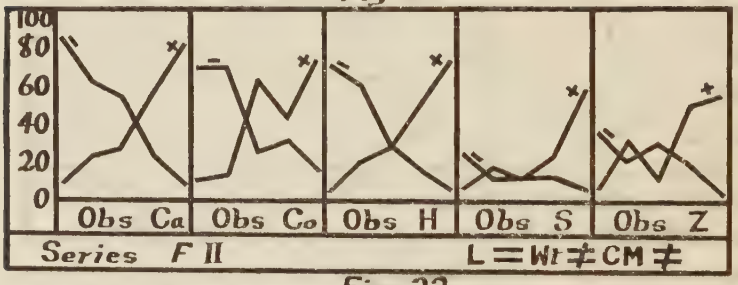

Fig 22

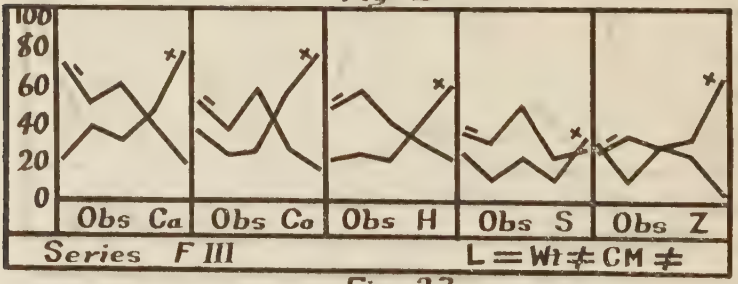

Fig 23

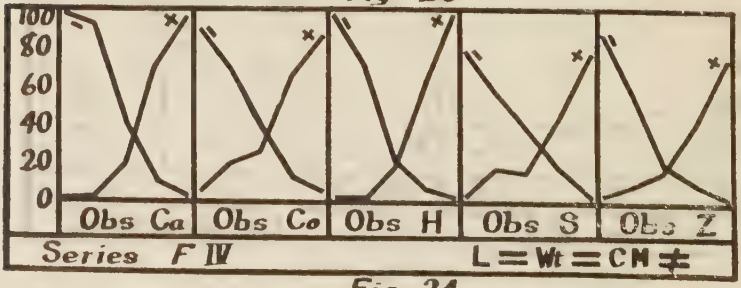

Fig 24

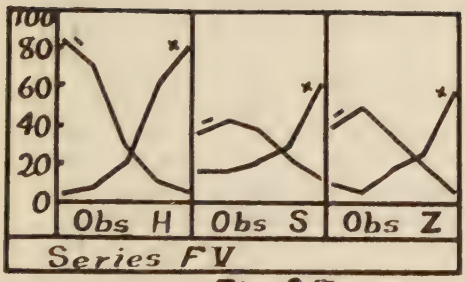

Fig 25

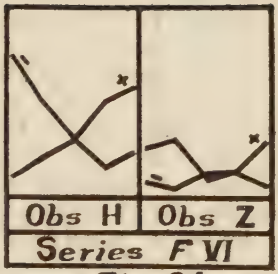

Fig 26

tice cf. Figs. 1 and 9) and where weight is the only incremented factor. The curves are flat; and there are inversions of the first order in every one save the curve for the 'longer' judgments given by F. It is obvious that there were, in this series, no sufficient sensory data for the differentiation of perceptions of length; the weight-increments, which were the same as those used in the preceding series, were not vital for the experience. Hence they cannot be held responsible for the results obtained earlier.

In spite of these curves, however, we believe that it would be a mistake summarily to dismiss the moment of weight as bearing no relation to length non-visually perceived. In Fig. 14, with weight and length varying, and in Fig. 17, with weight alone receiving an increment and a decrement, we have curves showing a tendency toward correlation between objective weight and perception of length; the lighter rods come to the *O*'s as 'short,' the heavy as 'long.' The tendency is especially striking for H in both series and for L with the heaviest rod in series B IV.[9]

This relationship finds its explanation in a gradual shift of attitude on the part of the *O*'s. They came, by degrees, to observe a single aspect, the intensive change, in the total complex (since this was the only variable present), and to report differences of intensity as differences of length. They were, naturally, determined in the direction of finding a difference; the judgment 'equal' did not mean, in many cases, the perception of equality, but the perception of not-different. It may be, too, that the introduction of the introspective series, necessitating the direction of attention upon the sensory experience, made for the translation of sensory cues into the meaning of length. We believe that, whether these series had been introduced or not, the *O*'s would have sought out some sensory cue within the complex as a means for making comparisons. Such a cue could never be adequate to the full perception of length, since this has as its primary condition not a simple attribute, inhering in a single sensation, but a ratio of intensities.

In this dilemma of having to make a judgment of difference, under the determination for differences of length, upon an inadequate sensory basis, the *O*'s seized upon the outstanding feature in the shifting complex mass, and forced that into service. Instead of apprehending the two intensities in rela-

[9]The two curves shown for H in Fig. 14 represent an earlier (dotted line) and later (full line) performance of these experiments. The change of result with shift of attitude is noteworthy.

tion, which is impossible except as they integrate in the perception of length, the *O*'s took the intensity of the 'kick' or of the 'pressure,' absolutely or in relation, as immediate data for judgment; the intensity of either or both of these pressures is affected by a change in weight as well as by a change in center of mass. The above results, accordingly, find an explanation which at the same time makes clear the true part played by weight in the judgment of length.

This shift of attitude is precisely what we might expect to take place; it is in keeping with all that we know concerning the 'natural' life-history of perceptions. The tendency is that, sooner or later, some aspect of a complex experience comes to stand for the whole; that a fragment, tag or remnant of the full sensory complement is effective to arouse and carry the meaning, fully maintained, that once accrued to the total process-complex.

But there is other evidence against the case for weight. In the experiments in which artificial wooden 'spoons' were used to receive the 'kick' in the one case and the 'pressure' in the other, the differences in the weights of the rods were not sufficient to call forth differences in the perception of length; in fact, the perception of length did not appear at all. And in series A III, where the center of mass was very near the forefinger (15-25 mm.) and varied by increments of only 1.5 mm., the perception of length was frequently lacking; the distributions of 'shorter' and 'longer' judgments (Fig. 3) shows flat curves with inversions of the first order. The more regular distributions of F and H are explicable.

F's once injured wrist necessitated a peculiar manner of taking the rods, and a dependence upon wrist-torsion for making the judgments. With a rod set as a lever in the hand, where the forefinger and the base of the thumb act as fulcrum and weight respectively, the weight or force is adequate to produce a torque in the wrist. A failure of F to render judgments of difference in this case would have proved perplexing: just as her objectively poorer results in A II were to be expected. H, unable for the most part to get the perception of length and, when it was present, unable to make judgments of difference, resorted to an individual way of taking the handles. Instead of employing the whole hand, he took the handle in such a way that in front it stimulated the forefinger alone, and at the back a very small area at the base of the thumb. By thus limiting the stimulated parts with the 'kick' and the 'pressure' (so to say) concentrated, he was enabled to make judgments. It is clear that one of two things

must have happened; either H singled out for observation the intensive changes of a single sensation; or the enhancing effect of the smaller area made smaller total-complex differences capable of carrying meanings otherwise unattainable. The former alternative accords better with the known facts. Although, therefore, H was set to report differences of length, yet by a process of substitution the inequality of intensity of the single sensation in the total complex came to touch off, directly enough for judgment, the meaning of difference of length.

Finally, series F I, F II, F III, F V and F VI demand a word of explanation. In these series the heaviest rod had its center of mass least far out and conversely, so that the two factors, weight and center of mass, ran counter to each other; they stood in an inverse ratio for the five variable rods taken in order. This result was secured by an addition to, and shifting of, the weight of the rods, in order to make them conform to certain requirements. In each one of these series either the 'kick' or the 'pressure' was the same for every rod, while the other factor increased in amount from rod number one to rod number five; the increments in series F I and F II yielded relatively equal decrements in the ratio of 'kick' to 'pressure;' in series F III gave relatively equal increments in the pressure itself; and in series F V and F VI gave relatively equal increments between the center of mass and the hand.[10] The results show marked differences between *O*'s: for some, the discrepancies of weight and center of mass cut across one another, so that the effect of the one practically nullified that of the other; for others, the differences of weight determined the judgments of length; for still others, the judgments of length reflected but slightly the opposing differences of weight. The same contradiction in results came out in series E, where we have very large increments of weight but equal centers of mass. Co and H gave hardly anything but equal judgments; S and Z gave judgments which correlate highly with weight. The fact that the judgments of two *O*'s do not correlate with weight is conclusive; the two perceptions are of different kind and, under constancy of determination, the one modifies the other but slightly even though they are at variance. The difference is that between an experience in

[10] In making our computations, we disregarded the facts that the pressure falls upon an area and not upon a point, and that the difference in the size of the hands of the observers somewhat changed the absolute values.

which a cue touches off the meaning and one in which a perception comes to full realization.

The following reports[11] taken from a much larger number illustrate *O*'s experience when set to judge differences of length by stimuli varying either in weight only or in weight and length. They supply twofold evidence for the position that differences of weight gave the perception of differences of intensity, and did not give rise to a true perception of difference of length. They show, on the one hand, that differences of weight were noted with contrary judgments of length; and, on the other hand, that differential judgments of length were touched off by differences of perceived weight,—the point being that the *O*'s could say that the judgment was one of difference of weight and not one of difference of length. They also afford proof of the statement that the arrangement of pressures within the pattern was identical for rods of different weight, the only difference being that of absolute intensity. The *O*'s evidently took the attitude of reporting the experiences upon which they based their judgment, although the instructions do not call for such an attitude. The reports are not, in all cases, rendered in strictly attributive terms; there can, however, be no mistaking their import.

Series A III: (3—5+). "There was present this time the notion of something out there beyond the handle. Can make weight-judgment always. The difference from stimulus to stimulus seems to be one of degree rather than one of pattern. This time a foundationless inference on basis of weight" (G). (3—5=) "Perception of greater weight with the second rather obscure. The clear thing was the pressure distribution in the hand, which was the same in both cases" (G). (5—3=) "Pressure-pattern same in both cases. Unequal intensity of pressure-sensations from front and back of hand give idea of length" (N). (3—1=) "First heavier. Idea of length from pressure on back of hand and pull on fingers. Second about the same degree of unbalance but lesser weight. The relation of the back and front pressures was the same in both cases, although the intensity was less in the second for both pressures" (N). (3—4+) "Greater pull in

[11]The experimental series from which the reports are taken is given at the top of each group. The numbers before the quotations indicate the rods used for comparison. For convenience, the shortest rod, or the one with the nearest center of mass or, in case they are of the same length and have the same center of mass, the lightest rod is designated as rod number one, the others coming in ascending order. Rod number three is equal, physically, to the standard. From these numbers and the table of physical moments, it is easy to determine the physical relations between any two rods involved in the reported comparison, since the order of succession in that table is the same. The judgment rendered in every case is shown by the sign +, =or—; + standing for longer, = for equal, — for shorter. These legends are used throughout.

wrist and greater pressure on fingers. End of handle presses up against palm of hand and sets up pull in wrist" (F). (5—3—) "First was heavier; more intense pressure on fingers. Heaviness gave length. Pull on end gave length" (F). (3—1=) "Pressure on fingers and pull on wrist same" (F).

It is to be noted that in these last judgments and in all others of the same kind *O* based his judgment upon the absolute intensity of a single pressure, or of both pressures, independently of their relation.

(3—5—) "I first perceived weight. Sole cue for length was pressure sensations of hand, especially forefinger. Aware of weight from muscular sensations. Attention to sensations from hand gave definite length. With second rod, I was again aware of heaviness at the end" (Z). (3—5+) "Sometimes there is intervention of the weight-factor. I am apt to assign greater length to heavier rods. By closer concentration on the pressures in the hand and especially on the fingers I can usually, on the basis of this criterion, judge the length and hence differentiate between the two factors" (Z). (3—2+) "With first, just bare pressure-complex carried over in memory-after-image. There was a little throat-kinaesthesis that meant medium. With the second experience, the pressure was the clearest part. It was perceived both qualitatively and quantitatively, but the quantitative aspect was prominent and set off the reaction *longer*" (H).

Here again we see the influence of the intensive factor taken in an absolute way. The same thing is true of the next record. We found, in support of Meumann on the comparison of time intervals, that the pattern of consciousness with the comparison stimulus differed in certain essential respects from the pattern with the normal stimulus. The latter usually resulted in a full realization of the perception of length; all the sensory data came forward; the former resulted in a very scanty perception of length, a bare meaning of more or less; the apparatus, set for giving length, responded to any cue.

(3—3+) "Pressure complex the clear thing in the first experience. With the second, the pressure at the two points was immediately perceived as greater and the response came" (H).

Series A IV: (3—1=) "I got length and a notion of rod from both. Second was heavier. Both easy balance. The pattern was the same but pressure more intense in the second" (G). (3—3=) "Got the notion of long rod from the first. Fluctuating pressure. Second less fluctuating but more intense. The two sorts of criteria give the same notion if one is not critical" (G). (1—3=) "No difference in unbalance but the second was heavier" (N). (3—5=) "First was slightly heavier. A definite idea that length was there, but can't give a comparative judgment" (N). (3—5+) "Little heavier pressure on fingers and pull in wrist a little greater with the second" (F). (3—2=) "Pressure on fingers and pull in wrist the same" (F). (3—4=) "With the first rod, I was first aware of a certain weight. Then attention was drawn to the sensations in the hand and I got a definite notion of length. It appears that I am always baffled by the determination of length in distinction to that of weight. If I do not take care, I confuse a heavier rod as being longer. Both weight and

length seemed to be determined by pressures in hand" (Z). (3—2=) "The first gave live contact-pressure with deeper dull pressure in forefinger; lively pressure of less intensity on base of thumb. Second experience less intense all round. Perception of length the same" (H).

The next reports also show both that there is a tendency for judgments of difference of length to be touched off by differences of absolute intensity, and also just the contrary: that differences of absolute intensity are ineffective to qualify the perception of length. As we have already remarked, the instruction to report differences of length, even when there were none, laid a heavy burden upon the *O*'s.

Series A VII: (3—1=) "Barest experiences. Just the same. Perception of an evenly balanced rod. When I report 'same' it is the sensory experience and not length that is the basis of judgment" (G). (3—3=) "With the first, a notion of length. Spatial pressure pattern. Second gave notion of heavy rod. Pressure perceived as weight and not as length" (G). (3—5=) "Nothing there to enable me to make the comparative length-judgment. Both uniform, static, dead. Second more intense, but did not carry meaning of length" (G). (3—2=) "With the first rod I had an immediate perception of length. This was clear. I got nothing, at first, with the second but weight" (Z). (3—1—) "First rod gave an immediate clear notion of length. With the second rod I was at first struck by considerably greater weight. Then in verbal-motor terms; 'which is longer?' The extent was limited by the points of weight-concentration" (Z). (3—5=) "The pressure-patterns were the same quantitatively and qualitatively. The second was perceived as equal, the judgment being part of the perception" (H). (3—2=) "First pressure-complex in the hand gave clear perception of length, a moderately long rod. With the second experience the pressure meant weight. Pressure more intense and static in quality. There was a tendency to say shorter" (H).

In series B III, where we used rods whose lengths, measured in terms of center of mass, were in the approximate region of the lower limen for the non-visual perception of length, but whose weight-increments were the same as in preceding series, we obtained more proof of the same kind.

Series B III: (3—1 No judgment) "Pressure on first finger and palm of hand in both. No muscular strain or deeper-lying sensations that I usually got. I seemed to be waiting for a pull downward on first finger; it didn't come, and I could not give a judgment of length" (S). (3—5=) "Meaning of length did not go beyond the handle. But the handle was stretched out. Pressure on finger and palm of hand and thumb. There was a strain-sensation, but it seemed as a bare weight. It came at the same time as pressure. It was more through the hand and a little in the wrist, not on forefinger" (S).

The following, also from the series in which we used the heavy rods, bring out the same points.

Series B IV: (3—2—) "The second experience was less intense and the judgment referred back to the first" (L). (3—5+) "The two experiences did not differ except on the score of intensity. I could not localize intensity or say how it was linked up with 'longer'"

(L). (3—1—) "Experiences were precisely homologous. The first was more intense than the second. This intensity seemed to insure or lead to the judgment" (L). (3—4+) "There was a clearly marked difference in intensity of pressure sensations in the hand. The greater intensity of the second did not carry with it a judgment of length difference" (L). (3—1—) "The second experience differed in absolute intensity and this intensity-difference went directly over into length" (L).

The next report, typical of a small class, indicates the effect upon the perception of length of shift of attitude. *O*, it will be remembered, was under a double determination; that of making a psychological report upon the process-contents of the experience, and that of making a perceptual judgment.

(3—5+) "The first thing with the second rod was sensations in the hand; those at the heel a little more prominent and intense. Almost immediately I noted a 'drawing' in the fore-arm which was more intense and 'drawing' than in the former case" (Z). (3—1—) "With the first rod, the sensations from the forefinger and the heel of the hand equally clear for a moment. The notion of length was very clear. With the second experience, I perceived sensations in the heel of the hand. Fairly definite notion of length. Then sensations in the arm with the verbal-motor 'heavier.' There also came a change in the perception of length. It became shorter. They were about equal before this time" (Z).

As regards these and the next following reports, it is to be borne in mind that, as is shown by the psychophysical results, the *O*'s were *not* able to make judgments of difference of length that have a significant degree of correlation with differences of weight. Failure to take the two sets of results together and to interweave them gives a false perspective.

(3—4+) "Pressure at base of thumb clearest part of experience. This 'live' pressure was more intense in the second case. The obscure dull pressure on the front finger was the same in both" (H). (3—1—) "The judgment had a purely sensory basis. The pressure complex was less intense in the second. The judgment came automatically without length being perceived" (H).

Finally, we cite a few reports from the last series, in which weight was the only incremented factor, to show that the perceptions of weight and length are differently determined, that the primary and secondary sensory processes in the two cases differ as to their meanings.

Series B VII: (3—1+) "The second experience less intense than the first. In the first, distinct strain in the wrist spreading to hand and fore-arm. The second noted because of lack of intensity" (L). (3—5+) "Prominent thing in the first experience was lively kinaesthesis in the fore-arm. The second experience was more intense. Pressure-complex in the hand gave rise to a conflict as to 'equal' or 'longer'" (L). (3—5=) "In both, which were similar, three complexes stood at focus; pressure from finger, dull pressure from base of thumb, and clear but not filled-out sensations from the arm. The three seemed to have a common background; in the second the background was of less intensity. The three factors were equal in all

respects" (L). (3—2+) "With the first rod, I had sensations in the forefinger from the beginning. These were the most prominent part of the experience throughout. There was an immediate clear perception of length. There was a little change in the sensations from the arm. These were superficial and disconnected from the experience. With the second rod, there were first sensations in the heel of the hand. A very indefinite notion of length. Then sensations from the forefinger and the elbow came in. Sensations from forefinger clearest. Notion of length cleared up" (Z). (3—4—). "With first, sensations of equal prominence in forefinger and heel of hand. Sensations of lower clearness in fore-arm. Fairly definite notion of length. Second rod gave an immediate notion of length, mediated by sensations in the forefinger. Much less clear sensations in heel of hand" (Z). (3—1+) "Sensations from heel of hand and from fore-arm came in. Sensations from fore-arm clearest. Very definite notion of length. Then sensations in the forefinger became practically the only component. Length increased in clearness. With second, sensations in forefinger most marked but vague sensations in heel of hand and in arm. Notion of length very clear and definite" (Z). (3—5=) "First, sensations in heel of hand most marked. Sensations in arm and forefinger less clear and less intense. Not a definite notion of length. Then attention went to the sensations in the forefinger. Sensations in the arm dropped out and sensations in heel and finger became equal. With second rod, first there was verbal-motor 'heavier.' At the same time there came in marked sensations in the forefinger; lesser sensations in heel of hand and in fore-arm. Sensations in finger more intense and deep-seated than in heel of hand. Perception of length came very clearly" (Z).

Center of Mass

Since we took as our criterion for the conditions that determine the formation of the perception of length the ability, again objectively determined, to make judgments of comparative length, we must look for that factor, if any such there be, between which and the judgments we find concomitant variation. Fortunately we find such a one; the distribution of judgments, in every series where the center of mass noticeably varied, gives an X or cross with no inversions of the first order; in every one where the center of mass was constant the curves are flat and irregular. (See Figs. 1, 2, 6, 9, 10, 11, 12, 13b, and 16.)

But if center of mass plays so important a part, as a moment of stimulus, in the arousal of the perception of length, it becomes necessary to inquire more in detail as to its mode of operation. This enquiry should lead us to an understanding of the psychology of the perception, and should contribute toward its psychological analysis. As has been previously stated, a rod or instrument in the hand or a tall hat on the head acts as a simple lever or couple: if, that is, the rod is held out in the horizontal plane, or the hat is worn slightly tilted.

Lotze has pointed out that the tilting is an essential condition of the 'feeling' of enhanced height and consequent greater significance. This means, first of all, that there are two opposing forces or pressures. If we hold a rod in the vertical, there is nothing but the weight; no notion of length arises. It is only as the instrument becomes inclined that the perception of length comes in; weight without an extended center of mass never gives rise to the perception of length; though we do not at all deny that, given a center of mass 'out there,' variations in weight may set off a kind of derived judgment of difference of length.

The absolute intensity of the two impressions can not be the basis for the judgment of length; for we judge a long light rod, which produces relatively weak pressures, as longer than a short heavy bar, which produces much more intense impressions. The answer to the question: What is the experiential foundation for the perception? thus becomes clear; our process of elimination and our introspective analyses lead us to the same result: *the ratio between the 'kick' and the 'pressure.'* In a short rod, the amount of 'kick' relatively to the 'pressure' is small; in long rods, the two pressures more nearly approach each other in intensity; with every change in center of mass there takes place a change in the ratio of 'kick' to 'pressure.' A sensation-complex of two opposed pressures, more or less fused in experience, differing in intensity within certain ratio-limits, is the sensory pattern fundamental for our perception of length as given cutaneously; though sensory or imaginal elements of other kinds may touch-off or carry the meaning. Thus it may be intensity, perceived as weight or taken as bare intensity; it may be the temporal factor; it may be the direction in which the pressures are perceived as acting upon the hand; it may be the strain sensations in the hand; it may be other processes or perceptions than these which touch off the meaning of length or which determine the judgment when we make a comparison. All such secondary cues influence the comparative judgment more than the absolute; they determine differences of length under conditions that would not admit them into the absolute judgment.

A change of ratio of intensity between our two pressures, then, is at the core of the perception of difference of length; a change realized only by varying the center of mass. A variable weight brings no corresponding change in the ratio of the two pressure-intensities; it increases both in the same relative proportion; the ratio remains constant.

Without going into a detailed discussion of the sets of

curves referred to in this section,—they speak for themselves, —we turn to the consideration of some special items of work. We have already found that, with the artificial thumb and forefinger eliminating the 'kick' and the 'pressure' in turn, the perception failed. We found, however, that when we attached the board to the arm in such a way that the band, holding the board to the arm, stimulated a single small area, the sensations from this point combine with those from the forefinger to give a perception of length. This result evidently means that sensations from other and more remote parts of the body, if they are opposed and if they stand intensively within certain ratio-limits to each other, will fuse into a total to give the perception. It is for this reason that the fisherman can feel the pull of the fish on the end of his line as 'out there;' he has the perception of the length of the fishing-rod, even though he hold it over the lower and under the upper parts of his arm. He might just as well hold it over the lower and under the upper parts of his leg; the sensations yielded up by these distant points of contact give the perception as immediately as do the nearer together and more practised parts of the hand. We made no determination of the precision of judgments of length when the sources of sensation are far apart on the body, as compared with the accuracy of discrimination when the parts are near together.

One other modification must be reported. For a short time we told the *O*'s to grip the handles very tightly. With long rods of considerable weight the perception of length was not wholly lacking; the ability to make judgments of comparative length, within the limits employed, was totally nullified. Whether there is or is not a perception of length, with rods of different length, thus depends upon the strength of the grip; if the grip be strong enough, the long rod ceases to be so taken. This can mean nothing more than that the small increments or variations in pressure are too slight to change the ratio in a perceptible degree.

In Table II we give the 'pressure' and 'kick,' their increments, their ratio to each other, and the change of ratio with successive rods, for a few selected series. The series given represent almost all the different combinations of moments employed.

Mention was made in the reports from those series in which weight was the variable of an experience that, while negating the factor of weight, yielded positive testimony to the importance of the two related pressures: it was called the feeling of balance or unbalance. In the following quotations

TABLE II.

Series	Rod	Fore Pr	F.Pr. Incr.	Back Pr	B.Pr. Incr.	Ratio of B.P:F.P.	Ratio Incr.
A I	1	348.23		153.23		1:1.6306	
	2	270.20	21.97	172.20	19.97	1:1.5691	.0615
	3	293.86	22.66	192.86	20.66	1:1.5185	.0506
	4	316.20	23.34	214.20	21.34	1:1.4761	.0424
	5	340.23	24.03	236.23	22.03	1:1.4402	.0359
A II	1	268.91		164.91		1:1.6306	
	2	286.74	17.83	182.74	17.83	1:1.5691	.0615
	3	304.57	17.83	200.57	17.83	1:1.5185	.0506
	4	322.40	17.83	218.40	17.83	1:1.4761	.0424
	5	340.23	17.83	236.23	17.83	1:1.4402	.0359
A III	1	170.06		74.06		1:2.2962	
	2	175.70	5.64	77.70	3.64	1:2.2613	.0349
	3	181.43	5.73	81.43	3.73	1:2.2280	.0333
	4	187.24	5.81	85.24	3.81	1:2.1966	.0314
	5	193.14	5.90	89.14	3.90	1:2.1667	.0299
A IV	1	314.06		218.06		1:1.4402	
	2	320.60	6.54	222.60	4.54	1:1.4402	.0000
	3	327.14	6.54	227.14	4.54	1:1.4402	.0000
	4	333.68	6.54	231.68	4.54	1:1.4402	.0000
	5	340.22	6.54	236.22	4.54	1:1.4402	.0000
B VI	1	787.50		587.50		1:1.3404	
	2	815.00	27.50	615.00	27.50	1:1.3252	.0152
	3	842.50	27.50	642.50	27.50	1:1.3113	.0137
	4	870.00	27.50	670.00	27.50	1:1.2985	.0128
	5	897.50	27.50	697.50	27.50	1:1.2867	.0118
B VII	1	808.80		616.80		1:1.3113	
	2	825.65	16.85	629.65	12.85	1:1.3113	.0000
	3	842.50	16.85	642.50	12.85	1:1.3113	.0000
	4	859.35	16.85	655.35	12.85	1:1.3113	.0000
	5	876.20	16.85	668.20	12.85	1:1.3113	.0000
F IV	1	352.50		252.50		1:1.3960	
	2	375.23	22.73	275.23	22.73	1:1.3633	.0327
	3	400.00	24.77	300.00	24.77	1:1.3333	.0300
	4	427.00	27.00	327.00	27.00	1:1.3058	.0275
	5	456.43	29.43	356.43	29.43	1:1.2806	.0252
F V	1	400.00		286.53		1:1.3960	
	2	400.00	00.00	293.41	6.88	1:1.3633	.0327
	3	400.00	00.00	300.00	6.59	1:1.3333	.0300
	4	400.00	00.00	306.32	6.32	1:1.3058	.0275
	5	400.00	00.00	312.35	6.03	1:1.2806	.0252
F VI	1	418.82		300.00		1:1.3960	
	2	408.99	9.83	300.00	00.00	1:1.3633	.0327
	3	400.00	8.99	300.00	00.00	1:1.3333	.0300
	4	391.74	8.26	300.00	00.00	1:1.3058	.0275
	5	384.18	7.56	300.00	00.00	1:1.2806	.0252

taken from the series in which center of mass varied, we have still further proof of a positive character.

Series A I: (3—4+) "Greater strain on back of hand. Pressure sensations from back of hand greater in second" (F). (4—3—) "Wrist same. Strain factor from fingers to wrist same. Push down on the fingers the same. The thing seems to depend on the pull down from away out there" (F). (1—3+) "Pull in wrist greater and more of 'feeling of going down;' pressure down on thumb and two small fingers. Also pull on back of hand. Pull on back due to end of handle pressing on palm of hand" (F). (3—2+) "The strain-feeling in wrist greater for the second. Also a pull on hand, especially on front finger and back of hand. A sort of stretch" (F). (3—3=) "Pressure alone vivid. Set for pressure. Perceived quantitatively. 'Long' applied to pressure. Notion of rod did not come in. In the second experience, the pressure was the clear part and set off the judgment automatically. Rod context came afterward" (G).

The above report implies, as does many another, a difference between the 'bare length' attitude and the 'length of *rod*' or objective determination.

(3—2=) "Positive judgment set off by hand-complex and slight increase as rod pulls down. This gives meaning that rod is there. Judged on basis of pressure-complexes which were the same in both cases" (G). (3—5+) "Nothing in the first except the perception of pressure and measuring of it. This carried in memory-after-image. 'Longer' came with the second quite automatically with increased pressure. I really judged in terms of heaviness. Length-notion came after" (G). (3—1—) "Resistance less with the second; it came right up. With the first there was more pressure on the back of the hand; the second, even pressure" (N). (3—3=) "I concentrated attention on the shoulder. The shoulder gives criteria for weight. The perception of length seems to come from the pressures in the hand" (N). (3—5+) "With the second, more intense pressure on the fingers and relatively more intense on back part of hand where handle comes against it. This gives length; the length gives pressure at two points" (N). (3—3=) "It is the balance-pattern in the hand that gives notion of extent. It is in this way different from mere weight" (N). (2—3+) "In lifting the first rod there was a lightness of pressure in the hand. The pressure in the hand, with the second, was greater as well as the weight" (Z). "I think in terms of length in relation to compactness or concentration of weight. That is, if the weight is closely compact, it may cause as great a pressure with a short leverage as a more distributed weight on a longer leverage" (Z). (3—4=) "In lifting the former object, I was conscious of an object of considerable length. In lifting the latter rod, I got a notion of weight and pressure in the hand due to leverage. The latter no longer than the former though considerably heavier" (Z). (3—3=) "The clear processes were pressure-sensations from forefinger and base of hand. Judgment was made immediately on basis of comparison of these two sensory complexes. No definite notion of length in either case. Pressure-pattern, that is, the relative distribution of pressure at these two points, was the sole criterion for judgment. They were the same in both cases" (H). (3—5+) "Pressure greater on back of hand. I didn't notice much difference in the forefinger" (H) (3—5+) "Again, pressure at those two points, only, came into the experience.

In lifting the second rod, the pressure seemed to be a little bigger spatially; larger rather than more intense. Gave rise to notion of greater length; greater leverage" (H). (3—4+) "The only mental processes which enter into the judgment at all are pressure sensations from the hand, especially from forefinger and base of hand. In this case, the sensations from these two points, particularly the back, were a little more intense with the second rod. This distribution of pressure gave me the perception of length, although no particular length was assigned to either of the rods" (H).

In the above series weight, as well as center of mass, was a variable component. The following reports were made when center of mass and length were variables.

Series A II: (4—3=) "Quantitative judgment of the first. Verbal-motor, 'great.' With the second there was a tendency to call it lighter. Then the pressures came to clearness and carried the meaning 'equal.' The reaction followed" (G). (3—1—) "Pressure-complex, qualitative and spatial, in hand. There was no notion of rod. In the second, the pressure-complex was clear. Judgment came immediately. Qualitative and spatial pattern and not weight or quantity is significant" (G). (3—3=) "The clear sensations came from the hand. The pull down on the second finger, and the use of the forefinger as guide while it is barely in contact with the handle. Also pressure from the base of hand" (N). (2—3+) "Pull on skin in addition to the greater pressure and pull of the second all gave meaning of greater unbalance" (N). (3—3=) "With first rod, pressure in hand the clearest part of the experience. Length was assigned mainly in terms of pressure in hand. Apparently forefinger acts as fulcrum between the sensations in back part of hand and arm, on the one hand, and length of rod, on the other. Can't differentiate any mark by which I become aware of weight separate and apart from those whereby I assign length: *i. e.*, at the same time that I assign length there is also a definite assignment of weight. When the weight association comes in, the judgment is mediate" (Z). (3—4+) "In first, I was aware of muscular sensations in the arm, then of sensations of pressure in my hand. There was immediate definite length. With the latter rod, there were also sensations in arm and hand. It appeared that the long rod was acting as a lever over the hand. This was assigned length due to the pressure exerted in the hand by the leverage" (Z). (3—5+) "More stretch or pull in wrist. More pull in back of hand with the second" (F). (2—3+) "Little pull in wrist with the first. The pull a little greater in the second. Seemed to be the same weight and the same pressure on the finger in both. Pull in wrist as if the thing reached out longer and gave more pull in wrist" (F).

It may be recalled that the pull in the wrist for F is the sensory experience set up by the back end of the handle pressing up.

(3—1—) "With first, pressure-pattern-complex clear. Second, sensations in forefinger first. Then sensations at base of hand set off judgment 'shorter.' These were less than with the former rod" (H). (3—3=) "Clear thing in first experience was pressure in hand. With second rod pressures in hand very clear and equal to the former experience. Judgment followed immediately" (H).

Series A VI: (3—5+) "Perceived the first as fairly long rod.

Criterion simply intensity of pressure. Pressure fairly intense and a little more so away from body. Second more vivid and alive. Pressure very intense on outer finger. Perceived as 'longer.' Then notion of long dipping rod" (G). (3—1—) "Got notion of length; part of immediate perception. Then sensory experience became clear; live, fluctuating, more intense away from body. Second, perceived immediately as 'shorter.' Perfectly uniform pressure without change" (G). (3—5+) "Greater pressure on fingers and greater pull in wrist with second" (F). (3—2=) "Pressure on fingers and pull in wrist same" (F).

By this time the perception of length came quite immediately, and the *O*'s were often unable to get a vivid sensory experience or a full perceptual realization of length before the meaning itself became clear. There is, moreover, some evidence that the meaning may develop without any process-content at all becoming vivid.

(3—5+) "With first rod an immediate definite notion of length in motor terms and it remained stable throughout. With second, much greater relative pressure and in a flash seemed very much longer with verbal-motor 'longer'" (Z). (3—2=) "The first gave immediately, in motor terms, a fairly definite notion of length. Sensations in hand then became clear. With second, again all at once, upon lifting the rod, I got notion of length in motor terms. Verbal-motor 'equal.' The pressure-sensations again became clear and were equal to the former. The critical comparison or criticism of the automatically rendered judgment based on pressures in hand" (Z). (3—4+) "Judgment made on quantitative basis. Second, pressure at base of hand more intense relatively to pressure on forefinger, and the entire pressure-pattern more intense than the first. First, like well balanced rod; second good deal of pull down to it" (H). (3—1—) "In first, pressure moderate, evenly distributed. A well balanced rod. An immediate perception of length. In second, pressure was much less *in toto* and pressure at base of hand very slight. A little rod tipping up. 'Shorter' came as a part of the perception of length" (H). (3—5+) "In all these cases, the perception of length comes immediately. Sensory basis becomes clear afterward. Pressure in first that of a well balanced rod; liveness gave meaning of moderate length. With second, pressure more intense; strong pull down. Tendency after judgment to call the second heavier. Intensity of pressure at base of hand meant 'longness'" (H).

The series in which we used the heavy rods gave us reports of the same general bearing.

Series B I: (3—5+) "Pressure more on three fingers and muscular sensation in fingers. In the second, intensity of pressure on palm of hand and base of thumb. More muscular sensation in the whole hand, in the second" (S). (3—5+) "Pressure and muscular sensations greater in second. Also deep pressure-sensation in thumb and greater tension in second" (S). (3—4+) "All in hand. Pressure a little in second. Muscular complex in hand. Hand adjusts itself a little differently to different lengths" (S). (3—2—) "Muscular tension in fingers. Pressure on thumb. Second, pressure on thumb and muscular tension in fingers. Pressure less in last experience" (S). (3—1—) "Second came up easier, and it didn't drag or pull the forefinger down as a long one would" (S).

The strain-sensations set up in the hand as the organism tends to resist the two opposing pressures and to hold the rod in the horizontal position, enter now as a new secondary factor for carrying the meaning of length.

(3—2—) "The meaning, length, is placed upon the differential pressure-sensations in the hand; *i. e.*, the greater or less pressure on the forefinger *versus* that on the heel of the thumb carries meaning of length somehow, not visually, projected beyond the hand. The hand has come to mean fulcrum" (L). (3—5+). "In the first rod the pressure-complex was clear. Deep pressure was especially prominent. In the second case, the strain-sensations in the arm seemed coordinated with the pressure-sensations in the ball of the thumb" (L). (3—5+) "The handle, in this experience, was grasped less tightly, therefore the differential pressure-complex was more definitely analyzed: the pressure-complex of thumb and finger from that of the palm of hand. Torque was localized in hand. How torque functioned in connection with the pressure-complexes, I can not say. This torque is all in the hand" (L). (3—2—) "Experience centered about sensations in the hand. In the first, a clear differentiation. Light pressure and contact from thumb clear. Also sudden and intense deep pressure from palm of hand. The second experience was the same in the main, only less intense, especially on the thumb. Judgment immediate" (L). (3—1—) "Experience of the usual sort in which the judgment followed immediately. Difference that demanded attention was localized in hand and was of temporal nature. Complex of pressure and kinaesthetic sensations whose course was slower in the first experience than in the second. As to region of hand, contrast between inner side of hand just behind forefinger, and the base of the thumb" (L). (3—4+) "First rod gave clear sensations in forefinger and less clear on back part of hand. Experience in lifting second, sensations of forefinger more intense. Also more extensive. Immediately judged it as 'longer'" (Z).

It often happened, as in this case, that *O* noted the difference of intensity at a single point, say the forefinger; a fact which might seem to contradict our general conclusion. The contradiction would be real, however, only if we were in face of something other than distribution of attention; if *O* did not in some way take account of the relative as over against the absolute variation.

(3—1—) "With the first rod, I experienced, first, fairly clear sensations in the hand, especially on forefinger and at base of thumb. With the second rod, I had sensations in hand, wrist and fore-arm. Attention not demanded at any one point" (Z). (3—4+) "I first noticed, in the first experience, sensations in the index-finger which were very intense and pressed the forefinger down tensely against the wrist. There followed, soon, sensations in ball of thumb. Second rod, somewhat similar experience for the first moment. Pressure on forefinger following, down to wrist, and lesser sensations at base of hand. These accompanied by slightly greater strain-sensations through the hand." (Z). (3—1—) "Dull pressure-sensations at base of thumb especially clear in the two experiences. Much less intense with a somewhat 'bright' quality in the second" (H). (3—3=) "The pressure from the forefinger and base of hand the same in the two experiences. The

clear observation of the sensory complex in the second followed the judgment, which seemed a part of the perception" (H). (3—2—) "The pressure on the forefinger was, in every observable respect, the same for the two experiences. The pressure at the base of the thumb was less intense in the second case. Also it had the meaning of 'liveness' upon it, due to a 'bright' quality and a temporal fluctuation" (H).

Since section B in a sense duplicated section A, only a part of the *O*'s were required to perform both series. It is for this reason that we have introspections from two or three only.

Series B II: (3—4—) "Strain in skin, forefinger and hand. The second more intense, with increased pressure on the thumb" (S). (3—1—) "Pressure in palm of hand, in first. A little strain in first finger. Less strain and less pressure in the second" (S). (3—4=) "In first strain in fingers and down through palm of hand all as one sensation. Second, same in distribution and intensity" (S). (3—1—) "Strain-sensations in finger and palm of hand. Pressure-pattern at base of thumb. Second, lack of strain-sensation in hand, less intense in fingers" (S). (3—5+) "Pressure on forefinger and at base of thumb the clear processes. Less clear muscular and strain-sensations through hand. Marked increase in intensity at base of thumb; less marked increase on forefinger. The second pressure more extensive, giving rise to notion of its pulling down more" (H). (3—2—) "The two experiences were qualitatively the same. The second was a little less intense at the base of thumb. The second also less extensive. Strain-sensations through the hand the same" (H).

Series B VI: (3—4+) "Most prominent distinction between the two, and which seemed to carry meaning 'longer,' was the temporal sequence in sensations at base of thumb. In the second they rose more slowly. Temporal course in first more rapid. This may have been confused with amount of change passed through. Greater range in second; *i. e.*, the relative amount of increase of intensity was greater with the second for this particular complex" (L). (3—5=) "The two experiences as usual, except for a peculiarity in second. Began by intense pressure on thumb, and this brought at once the meaning 'longer.' But pressure decreased and then increased on forefinger. This negated the earlier intense pressure against base of thumb" (L). (3—1—) "The sensation-area from forefinger constant and in background of consciousness in both. In first, the pressure at base of thumb showed a transitional change and rose to high intensity as a block of experience lifted out. In the second, the whole thing seemed a flat pattern with only a vaguely traced boundary between pressure on forefinger and thumb" (L).

All these reports from the introspective data corroborate the findings from the psychophysical series as presented in graphical form.

Synthetic Series

The best test of any hypothesis regarding the analysis of a perception is that of reconstruction under the observed conditions. If our assumptions are well founded, then the perception of an extent beyond the hand should be aroused by any two pressures, so long as these are kept between certain limits of

ratio of intensity, of spatial relationship, and of direction. Taking these facts as our point of departure, we set out to produce the perception synthetically.

The matter of thus setting up the length-experience with no length present reduced itself finally to the problem of devising a means by which the two opposing pressures could be applied to the hand (since this was the part of the body with which we had worked) in a way that should be under perfect control. We found that when we took two short pieces of wood like the handles, and pressed the one up against the base of the thumb and the other down upon the forefinger, our *O*'s gave immediate judgments of length: in fact they were unaware, according to their own report, of the substitution of the two short pieces for the one long rod. Further preliminary trials proved that the length, as perceived, could be made 'longer' or 'shorter' by alternately increasing or decreasing the 'kick' and decreasing or increasing the 'pressure;' and that the perception broke down if *E* increased either 'kick' or 'pressure' beyond certain limits, when *O* perceived the two pressures separately as two unrelated experiences. So far, however, our pressures were not subject to rigid control.

The problem demanded two physical pressures, which were to be resisted independently, to operate in opposite directions, to be stable in duration, definite in amount, and independently variable. The first apparatus consisted of a handle, with an oval hole cut through lengthwise, slipped over a small rigidly supported rod set in the horizontal plane. A short pin, set into small holes bored through handle and rod at right angles to their principal dimension and at close intervals, served as a pivot, so that the handle had a considerable latitude for movement up and down about the pivotal point. By altering the point of pivoting, the length of the two lever arms changed inversely, while at the same time the down-pressure of the fore end and the up-kick of the back changed in an inverse ratio. Since the effective physical pressure is a function of the length of lever arm and of the weight or force applied, these pressures could be determined and varied by assignable amounts; the weight, hung at the front end of the handle, tended to actuate rotation of the handle in the hand of *O*, who gently resisted the movement. The device was a success so far as the evoking of the perception of length was concerned. It was, however, ill-adapted to the evoking of judgments of comparative length, since *O* might, by using the pivot as a fulcrum, resist all force of the weight at either the fore or the back point of contact.

Next a split handle was arranged, with the top half pivoted in front and moving upward through a small arc at the back, and the bottom half pivoted behind and moving downward; the movement was produced by weights attached to cords which ran over pulleys. The two pressures could be varied at will, and must be resisted independently. The perception of length did not invariably result, for the *O*'s were immediately aware of the division in the handle, and might allow the one half to move through a relatively large arc while they held the other from moving at all.

This apparatus was given up as a failure, and in its place we made a handle with a smooth horizontal hinge at the middle; the back end being pushed up and the fore end pulled down by easily variable and definite amounts. *O* took the handle loosely and the weights released caused the handle to dip down in front and up behind, just as a rod would behave. So long as the

handle did not 'break' at the hinge, the perception of length was definite and controllable; but a 'break' destroyed the perception, since the two pressures were no longer 'in line.'

Finally we hit upon a simple and satisfactory arrangement; a handle suspended on a cord attached at the front end. Fastened to this handle were two weights; the one, fixed to the lower side at the front end, pulled down; the other, fastened to the back and by means of a cord run over a pair of pulleys, pulled up. There remained one disturbing factor; the handle was unstable; it seemed unattached. By inserting a light rod into the handle, the possible length-effect of which we overcame by a weight on a heavy wire set into the rod and bent back under the handle in such a way that the center of mass was at the point of the forefinger, we secured better results. But the rod was presently dispensed with. We suspended the front weight, which had been rigidly attached to the front of the handle by a short wooden piece, on a cord and so eliminated the rotation-effect due to the swing of the weight. After lengthening this cord which held the front weight, so that its pendular period was about the same as that of a normal rod which would give the same 'kick-pressure' ratio as the two pressures from the handle, we took out the rod; a bare handle remained.

The front weight was 250 gr.; the back pull was 140 gr., increased and decreased by 20 gr. increments. To be sure, the two pressures were not wholly independent of each other; if the pull or 'kick' did not come directly under the point of contact between the hand and handle, any increase or decrease of the pull would be reflected by a change in the amount of pressure necessary to counteract the weight in front. We can not be absolutely sure that with *O*'s whose hands differed considerably in size we met this objection. But even if the front pressure varied somewhat from the amount of the weight, it could have done nothing more than change the ratio of 'kick' to 'pressure;' it would have been a constant error for any one *O*. According as it increased or decreased the absolute intensity, it would have made the small changes less or more easily perceived.

Two features connected with the lifting of the handle called for special practice; *O* must lift the handle in such a way that the two pressures came on simultaneously, and must oppose the back pull sufficiently to prevent that end of the handle from moving upward.

Fig. 18 gives the graphical representation of the results; the abscissae correspond with the five settings of the back pull which alone varied. Here are comparative length-judgments made under the same instructions as the judgments with actual rods. The results speak for themselves. There can be no doubt of the actuality of the perception, or of the effectiveness of small changes in the intensity-ratio of 'kick' to 'pressure' for altering it: the perception of length can be synthetically produced, and is so accurately conditioned that very small changes in a single pressure bring about corresponding changes in the meaning of length. A comparison of the results of series F IV with those of F V and VI (Figs. 24, 25 and 26) shows that variation of a single pressure is less effective for determining the perception of length than is a variation in both

pressures, changes in center of mass being the same; and a comparison of F V and F VI shows that, when the fore pressure is constant (see Table II), the back pressure variable, and the center of mass still the same for corresponding rods in the two sets, we get higher percentages of the 'longer' and 'shorter' judgments than when the reverse is true. We had not the results of section F before us when we performed the synthetic work.

The reports from the synthetic series show that the same two pressures demand attention under the synthetic situation as in the case of true rods.

Synthetic Series: (3—5+) "Strain-sensations run down wrist and are fused with the hand-sensations. The pressures come on forefinger and at base of thumb. These latter are objective" (Ca). (3—5+) "Pressure on index-finger most intense. More intense in second. Pressure on other fingers less intense. Pressure on thumb was uniform" (Ca). (5—3—) "In first, pressure on forefinger. Irregularity in change of intensity of pressure. In second, pressure was constant in intensity. Pressure on thumb and ball of thumb. Constant sensations in other fingers" (Co). (3—5+). "Pressure-sensations on forefinger and thumb, more extensive on thumb with second. Pressure on forefinger slightly preceded that on thumb. The two must be combined to give the total experience" (Co). (1—3+) "Pressure on forefinger and in palm of hand, at base of thumb and at tip of little finger. More intense pressure on palm of hand and little finger in second" (Co). (3—1—) "Very intense pressure at base of first finger and intense pressure at base of thumb. The pressure in the second case less intense. They came in simultaneously" (S). (3—5+) "Pressure deep at base of first finger and pressure on thumb, about the middle. Clearer and more intense on finger. Area shifted outward a little. In second, deep pressure on finger, more intense and changed in area, more spread out than first. Pressure on thumb less clear, more intense than in first" (S). (3—2—) "Dull pressure on forefinger and at base of thumb in both. Vague sensations in lower part of arm. Less intense in second case. The pressure at base of thumb less in second, gave meaning of slightly less unbalance" (H). (3—4+) "With the second, the pressure at the base of the thumb was more nearly equal in intensity to that on the forefinger, than in the first. No qualitative difference noted" (H). (5—3—) "Marked pressure sensations on base of thumb, in the first. Less clear sensations on forefinger. With second, the sensations on forefinger clearest. Those at base of thumb less intense" (Z). (3—1—) "First experience carefully noted. No definite idea of length. Judgment part of second. When analyzed, it was less intense at base of thumb and less strain in hand" (L).

V. Secondary Factors

Visual Imagery

All *O*'s reported visual images, more especially during the early series; Z reported images of this kind, more or less, throughout the whole of the two years. In all cases, however, the image was an immediately accruing process which derived its meaning from the

sensory complex in the hand. Frequently it was instable, fluctuating with changes of eye-convergence. Frequently *O* volunteered the statement that it came after the judgment and served merely a confirmatory purpose; it was his justification. Furthermore, the coming in of visual images bears a close relation to the giving, under the comparative determination, of judgments of absolute length and of reflective judgments. In fact, visual imagery was never more than a secondary factor in the perception; it never came alone or even first in temporal sequence; it was far more likely than not to occur in the case of the reflective judgment or to follow the judgment; and it never appeared when the judgment was a part of the perception.

The following reports show the symbolic character of the images, the temporal order of their occurrence, and the relation they hold to the notion of length and to the comparative judgment.

"Image and eye-movement. No notion of length. Just rod lying out there going into third dimension. This image carried right over into the second experience. But it had nothing to do with the judgment. Judgment made on basis of pressure solely" (G). "As soon as judgment was rendered, a visual image meaning length came in fragmentarily. Also eye movement. All as I am reporting and after." (G). "After judgment, visual gray spot for a second. Some eye-movements entered into spacing. Confirming" (G). "Process, gray thing, developed by eye-movement. When sighting where I thought the thing would be, image came in" (G). "Visual image. Eye-strain determined distance" (G). "Accompanying judgment was a composite visual schema of two lines, one longer than the other, in a vague way connected with the hand. Visual image not at all connected with the judgment" (L). "Slight visual imagery, very schematic. Not at all a reproduction. Visual image supplementary" (L). "Visualization not important. Weak, hazy, no clear outlines, insignificant" (F). "Visualization. Second, lighter gray. Spatially related, eight inches between them. Darker one farther out. Second lighter, nearer in" (F). "Visual image of a flashing up of the end of the rod gives a rough outline of length" (N). "Scrappy bit of visual imagery came in after the judgment. It meant the end of the rod" (H). "When I had lifted the last rod, I had a visual image of hand lifting two rods in succession. At first the two were not definitely outlined as to length. In a moment the image of the first rod appeared as extended about two inches beyond that of the second. This image was vague except at the hand" (Z). "In this experience I had very clear visual images. Clearest part of image connected with lifting the last rod was at distant end of rod. End of rod was much heavier than first. It seemed as if it were bent down at the end" (Z). "As soon as I lifted the first rod there appeared a definite extent in space from me. The nature of this I do not know, for almost simultaneously I had a visual image of a rod the distant end of which was the clearest part. I rather think there was something there before the visual image appeared" (Z).

The introspections show a relation, more or less definite, between the quality of the image and the perceived weight or length. For F the darker gray always stood for the rod producing the more intense pressure; Z distinguished the dark, solid-grained oak from the soft, light colored poplar; and H occasionally correlated 'light and short' with bright tint. Always, however the perception of weight or of length was primary. There is also a relation between the tendencies to

visualize and to objectify the stimulus-object. So long as *O* perceived length as bare length, unrelated to an object, the visual image did not enter; when he perceived length as the length of a particular object, the objectification often took place in visual terms.

Muscular, Strain and Articular Sensations

James[12] says of projected movements that all the intervening space must be represented in consciousness; that when the projection is to the end of a walking stick, the extent of this stick must be represented in visual, tactual or kinaesthetic terms. James is concerned with projection and not with bare length; but in the case of judgments of absolute length, with objectification of the experience, we have a very similar condition. We found muscular, tendinous and articular experiences reported by our *O*'s, for the most part as sensory and not as imaginal. Z reported them more consistently and for a longer time than any other *O*; Ca reported them during the weight-series. These sensations compelled attention by their intensive changes. The arm seemed to be the seat of the only variable experience; and hence to afford the psychologically adequate basis for making differential judgments. It may be that Z had recourse to visual and motor imagery and to the reflective judgment more than any other *O* because for him the successive perceptions were differently determined. That is, the clear and, for him, the significant part of the first experience might be arm sensations, for the second, the hand-complex. Then the visual images evoked by the two would come together as the common element for making the comparison. One of his reports will make this state of things clear.

(3—1—) "With the first rod, I had, first, sensations in the hand. I did not get a definite notion of length from the sensations in the hand. Then there were very marked sensations from the arm. Meaning of length took on more definiteness. These sensations from the fore-arm remained clear throughout the experience. With the second rod, I had sensations in hand and also given at the same time the notion of 'lighter.' Visual image of picture given by Ebbinghaus in connection with a discussion of looking at two grays. Notion of 'lighter' pretty well marked. Verbal-motor: 'Is it shorter?' Notion of length seemed to vacillate. Again sensations in arm came in, and seemed to help in the attainment of definiteness of length. Visual image of the two rods of about the same length. Heavier one dark and of heavy wood; the light one, a poplar rod. Judgment based on the visual images" (Z).

Experiences of such elaborate pattern were rarely reported; the imagery was more often of the motor or kinaesthetic than of the visual type. But almost without fail, when the successive perceptions had a different sensory determination, *i. e.*, when different sensory processes were clear, some type of imagery served to represent at least one member of the two experiences which came in for reflective comparison. It is significant that the other *O*'s seldom reported kinaesthetic sensations, but they almost never gave the dual determination of the two experiences, and Z rarely reported kinaesthesis in both experiences. Though, when sensations from the arm were clear, the perception of weight almost always intervened, it has yet to be shown that sensation from this source can function in any other than a

[12]W. James, *The Principles of Psychology*, 1890, II, 196.

vicarious manner; it is more probable that the strain and muscular sensations from the hand and, to a lesser degree, those from the wrist are the psychological correlate of the meaning of length; the part they play would still be secondary and not primary.

When we used the wooden 'spoon' to take up the 'kick' of the rod, L reported a 'thinness' or 'emptiness' of the experience, which he attributed to the elimination of the hand and wrist kinaesthesis; this kinaesthesis had served as a background for the total experience. With the heavier rods, S repeatedly reports muscular and strain sensations from the hand aroused by the leverage of the rod held in the horizontal position. All these things are very different, however, from the kinaesthetic image an *O* would derive from having laid the rod along the body and leg, or from having run the hand along its extent.

The Temporal Factor

There were at least three, more or less distinct, ways in which the temporal factor entered into the complex of experience to affect the judgments both of length and of comparative length. These were the quickness with which a short or light rod came up, especially when lifted after a longer or a heavier rod; the time, independent of the lifting, within which the pressure-pattern formed in the hand; and the degree of steadiness exhibited by the pressure, as 'dead' and unchanging or as 'live' and fluctuating. When the first of these modes was an element within the complex of experience, the judgment 'shorter' or a tendency toward that judgment followed, if the rod came up quickly, and contrariwise if it came up slowly. The former happened much more frequently than the latter. If *O* postponed judgment until after the rod became stable, he frequently reversed his judgment, if it was a matter of difference of weight.

Some of the pressure-patterns, in accordance with the second principle given above, formed immediately when the lifted rod became an effective stimulus, and remained unchanged throughout the experience; others showed a well marked course of development in intensity, extent, or (less commonly) quality. In general, an increase of intensity or extent carried with it the meaning 'longer,' as did a shift of quality in the direction of ache or strain.

The 'liveness' of the pressure, required by the third principle, differed from the change mentioned under the second heading in that it was not a growth in a constant direction. As a rule, an unusually 'dead' static pressure carried the meaning 'long;' the 'live' fluctuating pressure, the meaning 'short.'

These three aspects of the temporal factor hardly ever occurred in combination in a single experience. Illustrative reports follow.

"As pressure creeps it becomes more intense on index finger and less intense on little finger. Second pressure intermittent, up and down, on forefinger" (Ca). "Second gave very slow intermittent pressures" (Ca). "Sensations on forefinger varied in intensity, also in a temporal way" (Co). "The difference is largely a temporal one in the forefinger. In the first, there was fluctuation; in second, constant. Especially fluctuations in muscular and tendinous sensations of the forefinger" (Co). "Resistance less. Came right up" (N). "Longer ones more springy; shorter ones come right up quick without any springiness. Greater pressure on the base of the hand with the longer rods is there immediately upon picking them up.

As soon as they are raised the distribution of pressure equalizes and remains constant" (N). "Second pressure at base of hand variable in time. It had a 'lively' quality, go and come" (H). "A sudden intensity means weight; length comes slower" (F). "Strain-sensation in fingers and palm of hand. Also deep pressure, mixed together, and it grew in intensity relatively slowly. This gave the meaning 'longer'" (S). "Second, slower strain-sensation in fingers and on thumb. Rose to maximal intensity more slowly than first and carried meaning 'longer'" (S). "The temporal course of processes seemed to be the most important. Torque and temporal bound up very closely" (L). "Second experience, whole experience less in intensity and showed none of the temporal course. Second, 'shorter'" (L). "Temporal sequence in this case clearly observed. Slower in second case; *i. e.*, the one to which 'longer' attached. The thumb-complex rose slowly to full intensity" (L). "Arm went up so much faster than it ought. Too much energy. It was surprisingly short" (C). "First, pressure 'alive,' 'gay.' Perception bound up with greater intensity that meant 'dead' weight and not fluctuation" (G). "Second, got more intense and spread out as if rod was bending down" (G). "I thought both long because of temporal thing, gradual increase in intensity of pressure as they were picked up. The proportional relation of amount of intensity and the rate of increase were noted" (G). "There seemed to be something like a resistance, a give or vibration or something, that gave the notion of length as distinct from the dead pressure from heaviness" (G). "Second seemed to go up. Sudden change in pressure, lightening of pressure, gave notion of 'short'" (G). "Fluctuation, more and then less intense, gave perception of fairly long dipping rod" (G).

Pressure Gradient

There are, no doubt, other secondary criteria upon which the perception of length, in the sense of this study, may be based. We have found, *e. g.*, that if a ring is made fast to the skin by means of a gummed tape, and a pull is exerted on this ring in a direction away from the body while at the same time a pressure of slightly different intensity operates upon a nearby spot on the skin, the perception of length follows: the extent is in the direction of the 'pressure' if this is more intense than the 'pull;' in the opposite direction, if it is less. Gradients in either direction are thus adequate to evoke the meaning of length, provided always that they are opposite and slightly different in amount. Moreover, the steepness and direction of the gradient, in the hand at least, are factors that on occasion play a part in determining the meaning of length.

The Absolute Length-Judgment

As in the case of lifted weights, the judgment of absolute length appeared; all *O*'s reported it at times. The judgment usually occurred with rods of the one extreme or the other; practically the second one was judged before it was lifted. The general instructions failed to the extent that a special disposition or attitude might develop which prevented *O* from doing his assigned task. Suppose, *e. g.*, that *O* judges the first rod as 'very long' in absolute terms; then he will expect, pre-judge, the next as 'shorter:' the consequent 'set' for the next rod is 'short;' the characteristic intensive, temporal and other differences are anticipated.

This absolute judgment is, however, of little concern to us in our analysis of the non-visual perception of length, since there is no indication that its determination is in any way different from that of the perception of bare length or of the perception of difference of length. We note only that the visual image, more frequently than any other process, carries the meaning of absolute length. Visual image, absolute length and the reflective judgment are bound up together. The two absolute meanings, visually determined, must be brought into a logical relationship before a comparison is possible. The situation is somewhat different in the case of judging the length of a single rod. Illustrative reports are:

"Visualized two points in space. First, far out; second, near. Two absolute judgments. Relative judgment an inference" (F). "I got the meaning of absolute length with the first. This judgment of absolute 'shortness' for the first gave me a 'set' for 'longer.' I expected the second to be longer. I can't say whether that imposed judgment or not" (H). "Absolute judgment of first as 'long.' Set to expect 'shorter'" (G). "Absolute judgment of first 'long.' Set off by pressure-pattern" (G).

VI. On the Computation of a Limen

The method of Constant Stimulus Differences may and usually does give a *DL*. Still following Urban we sought to use our data for this purpose. We computed the *h'* and *L'* for the results of the several *O*'s in the early series; but there we were halted. What is the unit of stimulus in terms of which a *DL* might be expressed? We had three sets of variables, all of which varied together in direct proportion. Which should be used in correlation with the psychological experience? At first we thought that the *DL* should be expressed in terms of weight; for applied weight is the mechanical stimulus which produces sensations of pressure, and resisted weight, muscular and strain sensations. But the results shown in Fig. 2, as well as those of the other series in which the weights were the same for all rods, prove that the *DL* cannot be found from the objective differences in the weight of the rods. So the graphs given in Figs. 4 and 17 show flat and irregular distributions; the 'kick' and 'pressure' were not equal or constant, but their ratio did not change. Weight is out of the question.

Before the work was far advanced we had decided that length, in and of itself, could in no way affect differentially the arousal of sensory experience; hence we could not correlate length with judgments of length. The results (Figs. 5 and 15) prove the justice of this conclusion. Nor are weight and length combined as co-variables adequate so to determine the perception that accurate comparative judgments are possible (see Figs. 4 and 14). Judgments of length were possible,

since the adequate stimulus for the perception of length was present, but they were undifferentiated. Length, too, is out of the question.

Can we, then, state a *DL* in terms of center of mass ? We have already remarked that the intensity-ratio of 'kick' to 'pressure' varies with every change in center of mass; and we have said that it is precisely this ratio that determines, psychophysically, the non-visual perception of length. The distance, in absolute terms, from center of mass to fulcrum-point at the forefinger varies directly with the intensity-ratio of 'kick' to 'pressure,' and the relation of this ratio to another of the same kind in two successive experiences determines the perception of comparative length. Have we here a moment in terms of which we may express a correlation between experience and stimulus-object ?

In the first place, we note that changes in this intensity-ratio are effective for modifying the perception only within certain limits, the lower of which we have fairly established. The *O*'s failed to perceive length when the intensity of the 'pressure' became twice that of the 'kick' (series A III, B IIIa and F I). The upper limit we did not determine. In the second place, a number of other secondary factors enter in to influence the perception of length. We have already discussed at length the relation of absolute intensity, as a correlate of weight, to the perception. In addition there are the elements of time, the character of the pressure-gradient, and the general sensory background from the muscles, joints and tendons of hand, wrist and arm, all of which not only touch off the meaning of relative length but may actually modify the perception.

The results from the 'spoon'-series prove, nevertheless, that there can be no perception of length without the two pressures. Here the perception appeared only if there were movement of the rod; as the rod swayed or vibrated there was generated a duality of impression within the limited area of the single contact-point. There is one instance in which the two sensations seem at first sight to come in succession rather than simultaneously: the case of the rod balanced on the end of the finger. As the rod begins to tip over, there comes the knowledge that it is an extended object and not a compact mass. The pressures are, however, not really successive; pressure becomes intensified in one part and weakened in the opposite part. If the end of the rod be pressed obliquely against the skin there is no perception of length. It is only as movement begins, causing the inverse change of intensity in opposite parts of the stimulated area, that we perceive length.

Thus the primacy of the two related pressures forces itself upon us once more.

We thus arrive at the conclusion that the primary item of experience, the underlying and essential condition for the perception, is a ratio between two opposing pressures held together by certain directional and temporal relations. But *for this ratio there is no directly corresponding element or moment in the stimulus-object.* Center of mass, it is true, bears a constant direct relation to this ratio; only, if we have recourse to it, the physical terms in which we express the limen will be two steps removed from the essential item of direct experience. The primary psychological condition of the perception transcends the stimulus-object.

VII. On the Application of Weber's Law

As regards Weber's law, there is a characteristic of our curves of distribution which may have an indicative value. In a majority of cases, when we consider those series only which gave X's, the curves for the judgment 'longer' do not rise as high as the curves for 'shorter,' and most of the inversions and plateaus lie on the upper side of the standard. Our steps, whatever their nature, represent (except in section F) an arithmetical and not a geometrical progression Stimuli which vary in this way should, under a strict working of Weber's law, give psychophysical results such as we obtained. Our interpretation of the perception of length as based upon a ratio of intensities is thus, so far, confirmed.

Conclusions

Our analysis shows that the non-visual perception of the length of a lifted rod is based primarily upon the experience of two opposed pressures whose intensive ratio falls within certain limits.

There are at least four factors which join with the two opposed pressures, singly or in combination, to complete the perception. These are absolute intensity of the impressions, their temporal course, the pressure gradient formed, and the muscle and strain sensations from hand and arm.

Visual and kinaesthetic images serve to establish the length in absolute terms. They may serve the end of comparison, but then imply a reflective judgment.

The perception is given as accurately in the passive as in the active state.

The psychological substrate of the meaning of length has no direct physical correlate in the stimulus-object.

The perception can be synthetically produced by the application, under certain conditions, of two opposed pressures.